Advancing Man-Machine Interfaces Through Embedded Force Measurement Technology

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Man-Machine Interface Requirements

- Electronically controlled interfaces and control-by-wire becoming standard in most military applications
- Military applications require precision not needed in industrial and commercial applications
- Robustness and survivability requirements in military applications are contrary to the low cost approach requirements of industrial and commercial interface product lines.
- Reliability requirements present in military applications are significantly higher then even the most “high rel.” industrial applications

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Military Man-Machine Interface

- Control of high precision optics - computer inputs for precision optics and fire control systems
- Computer input for mobile computing and communications systems
- Submersible electronics inputs.
- Fly-by-wire

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Three District Approaches

- **Position Proportional**
- **Force Proportional**
- **Non-proportional**

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Position Proportional Approach

Advantages

- Easier for untrained people to use
- More intuitive
- Has easily definable end conditions

Disadvantages

- Requires extra space for movement of handle
- More complex internal mechanism
- More prone to wear and degradation in conventional joysticks
- Lower precision

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Force Proportional Approach

Advantages

- Highly precise
- Smaller Space requirements in system
- Less complexity in input device
- Higher reliability

Disadvantages

- Not intuitive for untrained operators
- Over-force potential

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Non-Proportional Approach

Advantages
- Low Cost
- No over-force protection required

Disadvantages
- Can only control on-off functionality
- Switches are unreliable
- No precision

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Industrial Approaches to Man-Machine Interface

Standard Position Proportional Solutions
- Potentiometer based joysticks
- Optical joysticks and input devices
- Hall-effect input devices
- Industrial high-rel switches

Force Proportional Solutions
- Strain Gages based systems

Non-Proportional
- Switches are activated when levers are moved

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Conventional Man-Machine Interface Solutions

Technology	Advantages	Disadvantages
Potentiometers	• Industrial versions available in low cost packages (military versions extremely expensive) • Position Proportional	• Poor reliability • Require complex internal mechanisms • Prone to damage due to environments and dirt • Moving/rubbing parts wear easily • Low Life • Military and high reliability devices extremely expensive
Optical	• Low Cost • Position Proportional	• Required complex internal mechanism • Prone to damage due to environments and dirt • Low life
Hall-effect	• Extremely Low Cost • Position Proportional	• Extremely susceptible to EMI
Switches	• Low Cost	• No position proportional options available • Noisy • Prone to damage due to environments and dirt • Low life • Poor reliability
Conventional strain gages	• Force proportional • No moving parts • Increased reliability over other technologies listed	• High cost of strain gage application • Limited configurations • Cross-talk • Not time or temperature stable • Susceptible to noise • No position proportional options available

The Bokam Approach

Adapt High Reliability Sensor Technology to Input Devices to create systems that:

- High reliability and extreme live
- Have no moving or rubbing parts that can wear over time
- Provide Both a force proportional and a position proportional configuration in the same basic package size
- Develop an input device product line based on building blocks that can be combined to solve the most obscure application requirements without substantial NRE effort
- Create a cost sensitive product line.

The Base Technology

- Application and firing of strain sensitive materials directly into the diaphragm or substrate.
- Resulting element contains an imbedded set of strain gauges that do not rely on bond lines or epoxy for adherence to the substrate.
- Elements are deposited onto the substrate in a full whetstone bridge configuration.
- New proprietary processing techniques have been developed to allow for the deposition of strain gauge materials onto stainless steels and pin-corrosion resistive steels while maintaining dielectric isolation between the gauge and the base material.
- Proprietary barrier creation materials and processes are used to limit ion migration and create extreme temp solder joints.

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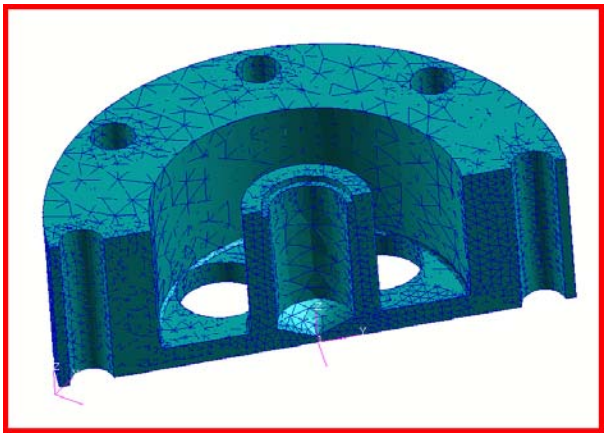
The Base Technology



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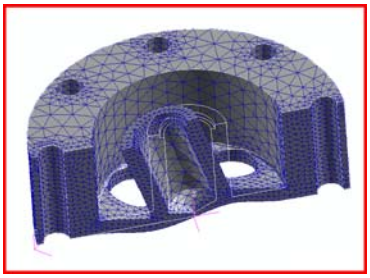
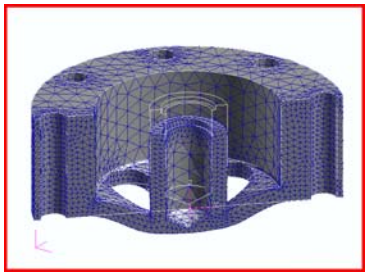
The Base Technology





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The Base Technology Capabilities

- Un-amplified outputs of full bridge sensor with 10V applied can be as high as 150-200mV (with 100mV as typical output with high safety margin)
- Operating temperatures from cryogenic to 500F
- Output stable over time and temperature
- Technology and processes adaptable to low cost high volume OEM applications

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The Bokam Approach - Notable Achievements

- Aurora product line named *EDN Magazine* Innovation of 1997 Finalist
- DX-300 Series of Sensors named Editors Choice for outstanding sensor development by *Electronic Products Magazine*
- DX-300 Series named EDN Magazine Innovation of the year for 1998
- DX-400 Series named Best of Sensors Show by Editors of Sensors Magazine for 1999
- DX-300M Series named in best 100 new products for 1998/1999 by leading European Medical Design Magazine
- The Smart Washer™ Named Best of Sensors Expo 2000
- Developed an engine embedded, production bearing thrust measurement system
- Developed a direct percent aeration, foam measurement and direct pump cavitation detection system and technology

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Technology Advantages

- Strain measurement circuitry embedded in the steel or ceramic surface.
- No organic materials
- High gage factor and sensitivity
- Increased stability and reliability
- Increased survivability and life expectancy
- Process highly automated and repeatable
- Manufacturing processes lend themselves to high volume production

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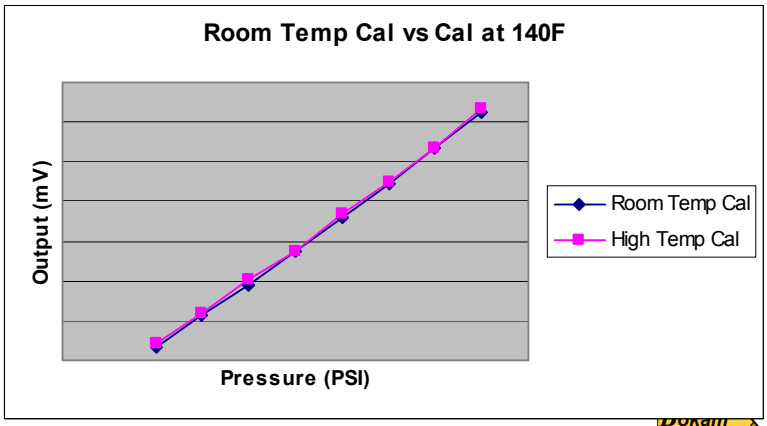
Technology Advantages - Thermal Stability



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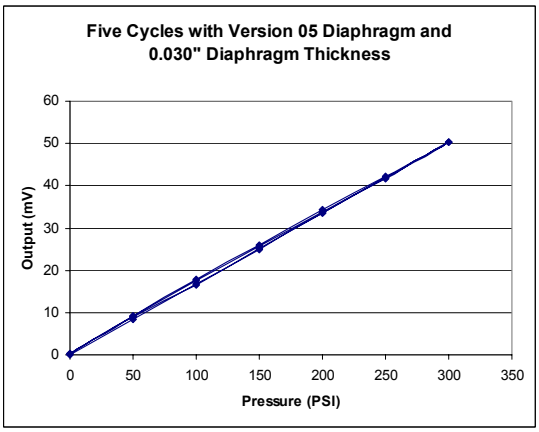
Technology Advantages - Repeatability and Stability



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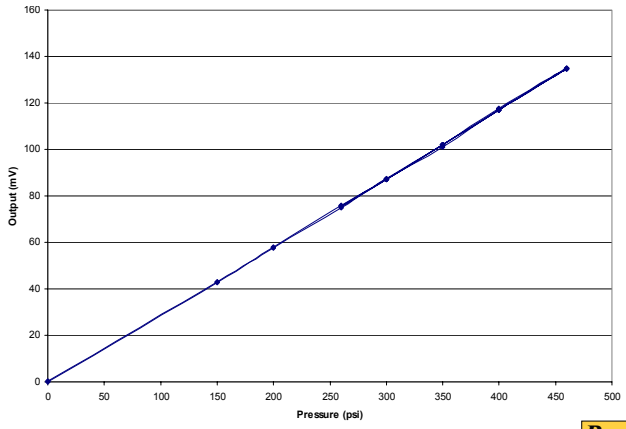
Technology Advantages - Signal Integrity



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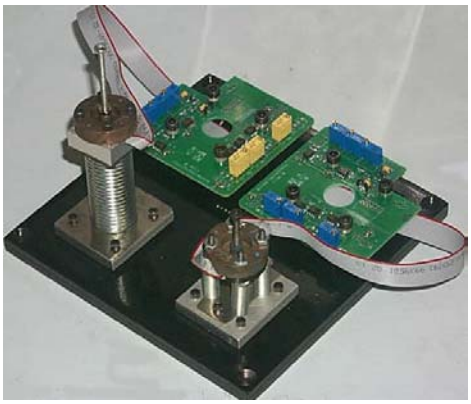
Mechanical Interface Innovations



Addition of compliant elements to force sensor create a position proportional device without degradation in sensor configuration or performance

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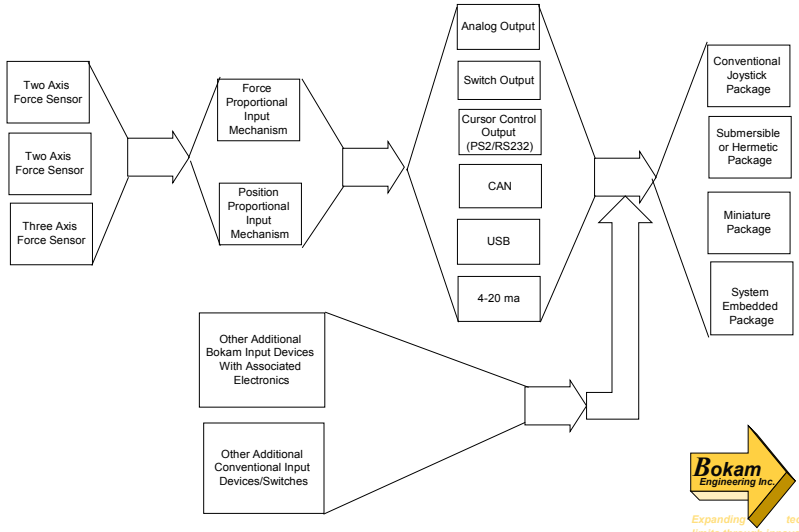
Modular System Approach



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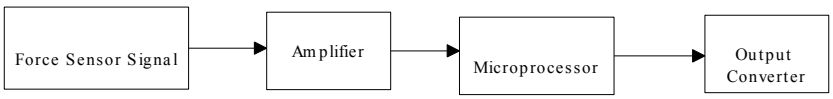
Signal Processing



* Number of Axis
* Hand/Finger/Foot
* Mechanical Package
* Input Mechanism

* Dead Band
* Span
* Cruise Control
* Dynamic Stability
* Switching Functionality

* Analog Output
* CAN
* USB
* PWM
* Switching
* 4-20 mA

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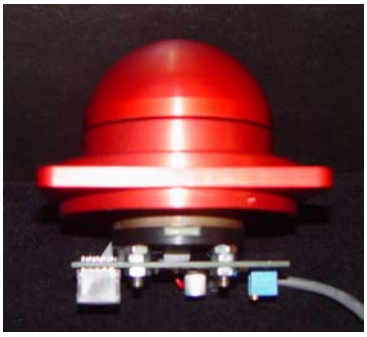
Products - The Dome



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The Gadol Joystick

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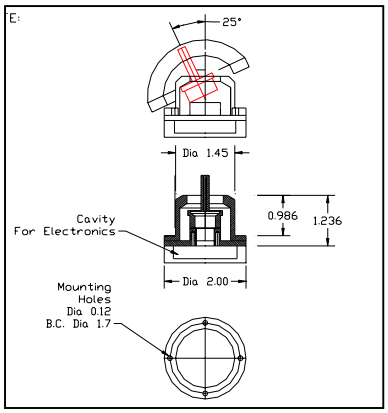
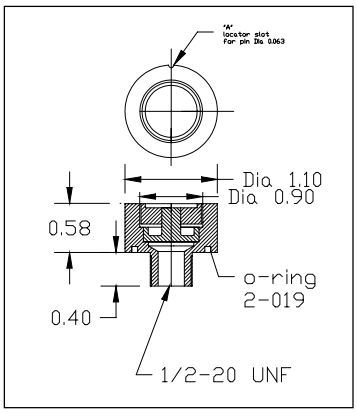
Products - Miniature Joysticks





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Products - The Neptune Series

- Non-compliant Stiff Stick Interface
- No contacting, rubbing or optical elements
- Non-magnetic construction to minimize system detection
- Fully submergible field tested and qualified by US NAVY for underwater use dive applications
- Embedded strain sensor technology allows for incredible reliability and long life at continuous operation in an abusive environments

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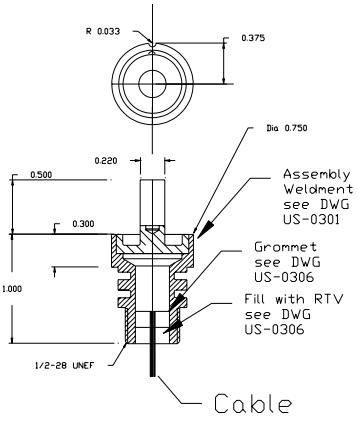
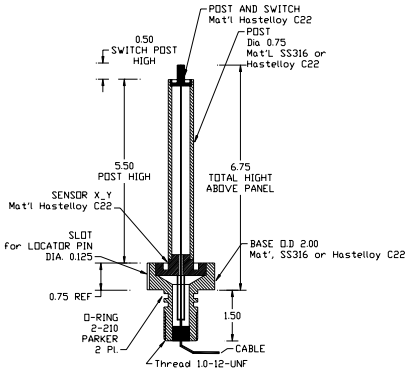
Products - The Neptune Series





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Neptune Series - Systems

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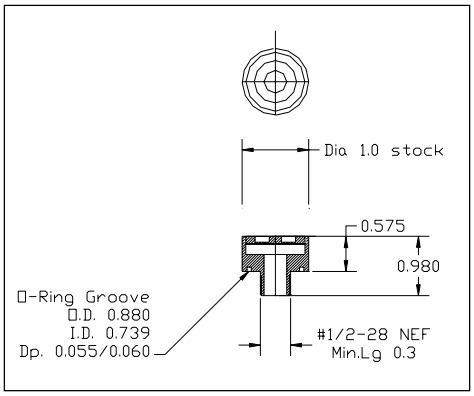
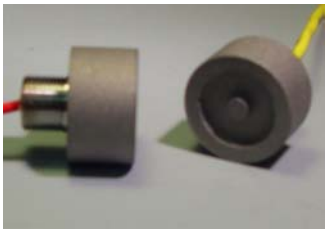
Solid Steel Push Buttons





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Pedals and Foot Operated Controls

- Position Proportional
- Force Sensor Based
- Redundant Springs
- Fail-to-off configuration
- Adaptable to standard pedals

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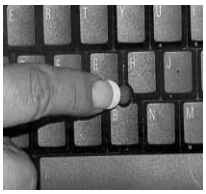
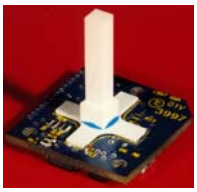
Products - Embedded Systems



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The Bokam Advantage

- High Precision of movement
- High reliability and life in excess of 10,000,000 cycles
- Resistance to environmental exposure
- Modular system configurations and interfaces
- Force and position proportional interfaces in the same package size
- Diver proven devices
- Extensive Heritage of force sensors and input devices
- Cost effective

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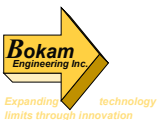
Applications

- Diver Input Devices and Cursor Control
- Fire and guidance control
- Fly-by-wire
- Remote vehicle controls
- On-board vehicle controls



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